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Messages from the Laboratory

BY ROGER SPERRY

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When it comes to saying a few words about our research, I am forced to hedge a bit. I am committed to not discuss our neurosurgical patients and their symptoms outside of medical or scientific settings. So I have been asking myself what else there might be of broad general interest. These days we're supposed to ask, "What's relevant?" or, according to the new RANN formula, "What is there in our science that might lead to a prospectus for social change?" Well, I can't speak to this exactly; but I can pick out three facets of our work where the kind of message that we get from the laboratory seems to differ somewhat from that coming from the public media or society at large.

Plasticity and Nature vs. Nurture

The first of these concerns the plasticity of brain organization and human nature. Back when we first began to work in this area, neuroscience was thoroughly sold on a kind of super plasticity in brain function. Among other things, the functional interchangeability of nerves for nerve surgery was taken for granted. Having its wires crossed by the neurosurgeon was no problem at all for the brain back in the 1930's.

When a damaged nerve like that supplying the muscles of the face had been replaced surgically by a nearby healthy and more expendable nerve—like that for lifting the shoulder, for example—the initial effect was associated movements in the face whenever the subject tried to lift his shoulder. However, the doctrine of the day said that the patient need merely go home and practice in front of a mirror and shortly the plastic brain centers would undergo reeducation to restore normal facial expression, mediated now through the brain centers and nerves designed for shoulder movement.

Efforts were being made to restore function to legs paralyzed by spinal cord lesions by using one of the main nerves of the arm still connected to the brain centers. The arm nerve was dissected out full length, tunneled under the skin, and connected to the leg nerves to take over the function of the paralyzed limb. Only an early report—not the final outcome of this effort—appeared in the literature, perhaps for reasons that are now understandable. However, exactly the same operation was later reported to be a functional success in experimental tests with rats during the 1930's. The motor, the sensory, and even the reflex functions of the paralyzed hind limb were said to have been restored through the transplanted nerves and brain centers of the forelimb.

The nervous system generally appeared in those days to be possessed of a wholesale behavioral plasticity or, as one authority put it, "a colossal adaptation capacity almost without limit." The followers of Pavlov in Russia and of John Watson in this country were speculating (justifiably it seemed) that it should be feasible with appropriate early training and conditioning techniques to shape human nature into most any desirable mold and thus to create a more ideal society.

This kind of thinking was reinforced by various other views of the 1930's; in particular, the prevailing doctrine on nerve growth told us that fiber outgrowth and the formation of nerve connections in the brain during development is essentially diffuse and nonselective. At that time there seemed to be no way by which the nerve circuits for behavior could be grown into a brain directly —that is, prefunctionally through inheritance without shaping by experience. It was supposed that the adjustment of brain connections depended entirely on function and began way back in the earliest movements of the fetus *in utero*—continuing from then on through trial and error, conditioning, learning, and experience.

Last April, Roger W. Sperry, Hixon Professor of Psychobiology, received the 29th annual Passano Foundation Award for achievement in medical science. "Messages from the Laboratory" is adapted from his speech at the dinner on that occasion. A more detailed account of the psychobiology research program may be found in the November 1968 issue of **Engineering and Science.**

Our experimental findings during the 1940's brought, of course, a direct contradiction amounting to a 180-degree about-face on these matters. As we now know, nerves are not at all functionally interchangeable; the brain is not all that plastic; and the growth of nerve paths and nerve connections in the brain is anything but diffuse and nonselective. Neural circuits for behavior are definitely grown in, prefunctionally under genetic control, and with great precision in an enormously complex chemical pre-programmed control system.

It is not just to recall old times that I go back through this history. The point is that the early views that became deeply entrenched all through the 1920's, '30's, and well into the '40's still have not been completely shaken off in areas outside the biomedical sciences. The lingering after-effects of the earlier doctrines may still be found in related disciplines like psychiatry, anthropology, and sociology and also in society at large. In other words, the majority of us still have a tendency to underestimate the genetic and other innate factors in behavior.

This impression comes not only from the earlier work just mentioned, but it continues to be reinforced repeatedly from many different angles. For example, in regard to cerebral dominance and handedness in man, the latest theory, as proposed by Levy and Nagylaki, suggests a two-gene, four-allele model with one gene determining which hemisphere of the developing brain will be language-dominant and a second gene determining whether the preferred hand will be on the same side or opposite the language hemisphere. Counting the recessives and dominants, this gives nine different combinations of inherited gene types or genotypes for handedness and cerebral dominance in man, some of the left-handed types, of course, being much more resistant than others to reversal by training.

Now the left and right hemispheres of the brain are each found to have their own specialized forms of intellect. The left is highly verbal and mathematical, and performs with analytic, symbolic, computer-like, sequential logic. The right, by contrast, is spatial, mute, and performs with a synthetic spatio-perceptual and mechanical kind of information processing not yet simulateable in computers. It is very impressive and compelling in neurosurgical patients with left and right hemispheres surgically disconnected to see the same person (some claim there are two persons in the one) approach the same problem, work it, and reach a solution in consistently different ways with quite different strategies, depending on whether the subject is using his left or his right hemisphere.

In other words, these nine genotype combinations, representing different balancing and loadings of these left and right mental factors, provide just in themselves quite a spectrum for inherent individuality in the structure of human intellect. Left-handers as a group have been shown to be different statistically from right-handers in their mental makeup—that is, in their I.Q. and other test profiles. Similarly, males come out differently from females. And females masculinized *in utero* or those lacking one X chromosome come out differently from normal females.

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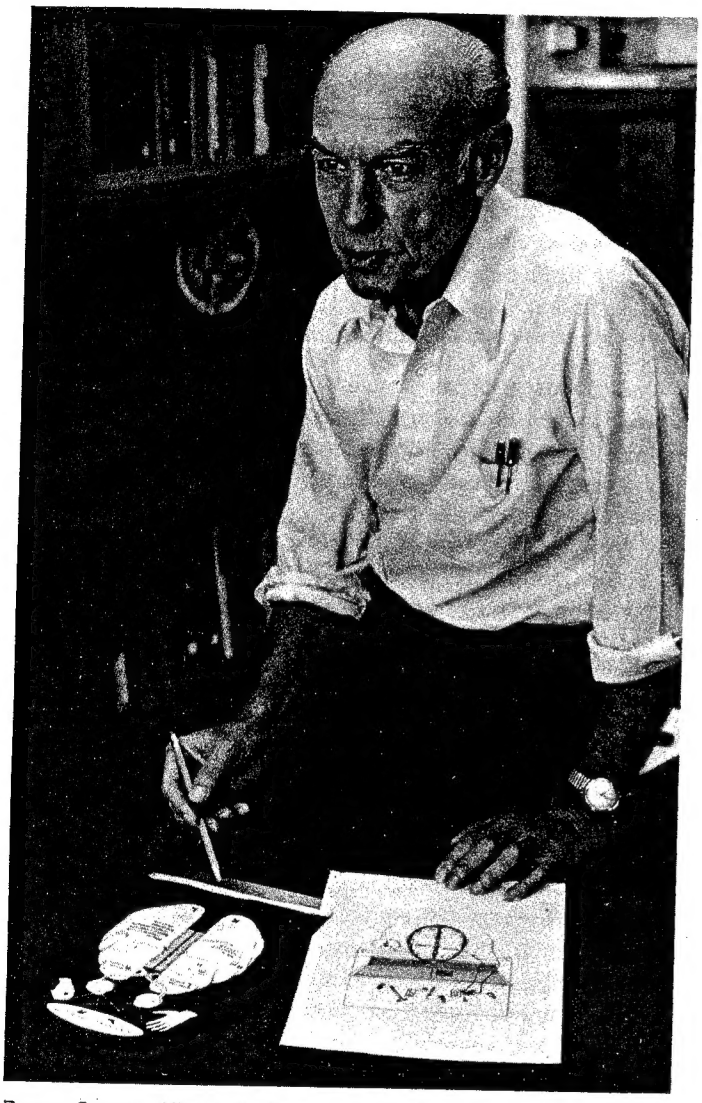
Many kinds of tests have shown that the right hemisphere is particularly talented and superior to the left in visuo-spatial abilities. This specialty of the so-called minor hemisphere, according to a current report by Bock and Kolakowski, is tied to a recessive sex-linked gene and is shown to exhibit a cross-correlation pattern of inheritance from parents to offspring that effectively rules out environment, experience, or any known theory of child development or nurturance.

When we add up all this—and much more—related evidence, we come out with a greatly heightened respect and appreciation for innate individuality. The degree and kind of inherent individuality each of us carries around in his brain—in its surface features, its internal fiber organization, microstructure, chemistry—would probably make those differences seen in facial features or in fingerprint patterns look crude and pale by comparison.

The Neglected Minor Hemisphere

We turn now to a second message that emerges from the



Roger Sperry, Hixon Professor of Psychobiology. His research strongly suggests that our present educational system—with its heavy emphasis on early training in the three R's—discriminates against the brain's minor hemisphere, which has its own perceptual, mechanical, and spatial mode of apprehension and reasoning.

findings on hemispheric specialization and which tells us that our educational system and modern society generally (with its very heavy emphasis on communication and on early training in the three R's) discriminates against one whole half of the brain. I refer, of course, to the nonverbal, nonmathematical, minor hemisphere, which we find has its own perceptual, mechanical, and spatial mode of apprehension and reasoning. In our present school system, the minor hemisphere of the brain gets only the barest minimum of formal training, essentially nothing compared to the things that we do to train the left, or major, hemisphere. (As a curious aside here, statistics indicate that athletic abilities correlate with enhancement of visuo-spatial mental ability. It follows as an interesting conjecture that advancement in our understanding of the cerebral substrates of intellect could make for a slight comeback in the old prestigious image of the "strong, silent man" of pioneer times—an image that is much submerged, of course, in our present-day verbal society.)

Behaviorism in Question

A third and final message for social change that we get from the world of the laboratory is a complex one and cannot be summarized simply.

One of the more important things to come out of our brain research in recent years—from my own standpoint, at least—is a modified concept of the nature of the conscious mind and its relation to brain mechanism. The new interpretation, or reformulation, involves a direct break with long-established materialistic and behavioristic thinking that has dominated neuroscience for many decades. Instead of renouncing or ignoring consciousness, the new interpretation gives full recognition to inner conscious awareness as an important high-level directive force or property in the brain mechanism. The conscious mind no longer is set aside as a passive correlate, but becomes instead an essential part of the brain process endowed with causal potency. The phenomena of inner experience are conceived to be "emergent" properties of brain activity and become causal determinants in brain function.

On these new terms consciousness is given a use, a reason for being, and for having been evolved in a material world. Not only does the brain's neuro-physiology determine the mental effects, as has generally been agreed, but now in addition the emergent mental operations are conceived in turn to control the component

neurophysiology through their higher organizational properties and the universal principle of the power of the whole over its parts.

This revised interpretation, since its appearance about ten years ago, has gained considerable acceptance and support. After more than 50 years of strict avoidance on Behaviorist principles, in the last 5 years, terms such as "mental imagery" and visual, verbal, auditory "images," and the like have exploded into wide usage as explanatory constructs in the literature on cognition, perception, and other higher functions.

The revised interpretation brings the conscious mind into the causal sequence in human decision-making—and therefore into behavior generally—and thus back into the realm of experimental science from which it has long been excluded. This swing in psychology and neuroscience away from hard-core materialism and reductionism back toward a new, more acceptable brand of mentalism tends now to restore to the scientific image of human nature some of the dignity, freedom, and other humanistic attributes of which it has long been deprived by the behavioristic approach.

Old metaphysical dualisms and the seemingly irreconcilable paradoxes that formerly prevailed between the realities of inner experience on the one hand and those of experimental brain science on the other become reconciled today in a single comprehensive and unifying view of mind, brain, and man in nature. Within the brain, we pass conceptually in a single continuum from the brain's subnuclear particles on up (through atoms and molecules to cells and nerve circuit systems without consciousness) to cerebral processes with consciousness.

These changing concepts of mind substantially alter the general image of man and his role as drawn in the Behaviorist tradition, and also bring other major departures from traditional materialist doctrine.

When subjective values are conceived to have objective consequences in the brain, they no longer need be set off in a realm outside the domain of science. The old adage that science deals with facts, not with values, and that value judgments lie outside the realm of science no longer applies in the new framework.

Instead of separating science from values, the present interpretation (when all the various ramifications and logical implications are followed through) leads to a stand in which science becomes the best source, method, and authority for determining ultimate value and those ultimate ethical axioms and guideline beliefs to live and govern by. By science here, I refer broadly to the knowledge, understanding, insight, and perspectives that come from science. But more particularly I am thinking of the principles for validity and reliability and credibility of the scientific way as an approach to truth—insofar as the human brain can comprehend it. In other words what has been called "Scientism" gets a new boost now, with added dimensions and a whole new look.

On the present terms human values become very much a problem for science, and in certain respects perhaps the most important problem today in the whole of science. Viewed objectively, human value priorities stand out as the most strategically powerful causal agent now shaping events on the surface of the globe. More than any other causal system with which science now concerns itself, the human value factor is going to determine the future.

I tend to rate the problem of human values Number One for science in the 1970's, above the more concrete crisis problems like poverty, population, energy, or pollution on the following grounds: First, all these crisis conditions are man-made and very largely products of human values. Further, they are not correctable on any long-term basis without first changing the underlying human value priorities involved. And finally, the more strategic way to remedy these conditions is to go after the social value priorities directly in advance, rather than waiting for the value changes to be forced by changing conditions. Otherwise we are doomed from here on to live always on the margins of intolerability, for it is not until things get rather intolerable that the voting majority gets around to changing its established values. It is apparent, further, that other approaches to our crisis problems already receive plenty of attention. It is the human value factor that has been selectively neglected and even considered, on principle, to be "off limits" to science.

The upshot of all this would in effect promote science into a higher social role above that of the provision of better things for better living—or the prediction, control, and understanding of natural phenomena. Science on these terms becomes a source and arbiter of values and belief systems at the highest level—man's best channel for gaining an intimate understanding of and rapport with those forces that control the universe and created man. □